

8. Switchgear and switchgear installations for high voltage up to and including 52 kV (medium voltage)

8.1 Switchgear apparatus (< 52 kV)

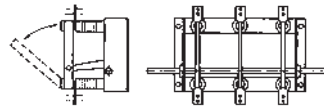
This voltage range is generally referred to as "medium voltage", even though the term has not been standardized anywhere.

The principal terms relating to switchgear are defined in section 10.1.

8.1.1 Disconnectors

The classic design of the disconnector is the knife-contact disconnector (Fig. 8-1). It has become less common with the increasing use of withdrawable circuit-breakers and switch-disconnectors. This functional principle is now again becoming more frequent in gas-insulated switchboard technology.

Fig. 8-1
Medium-voltage knife-contact disconnectors



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The blades of knife-contact disconnectors installed in an upright or hanging position must be prevented from moving by their own weight.

Disconnectors can be actuated manually and, in remotely operated installations, by motor or compressed-air drives.

8.1.2 Switch-disconnectors

Switch-disconnectors are increasingly being used in distribution networks for switching cables and overhead lines. Switch-disconnectors in connection with HRC fuses are used for protection of smaller transformers.

Switch-disconnectors are switches that in their open position meet the conditions specified for isolating distances. General purpose switches can make and break all types of operating currents in fault-free operation and in the event of earth faults. They can also make and conduct short-circuit currents.

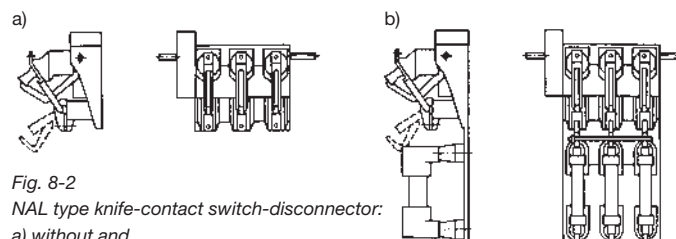


Fig. 8-2
NAL type knife-contact switch-disconnector:
a) without and
b) with fuse assembly

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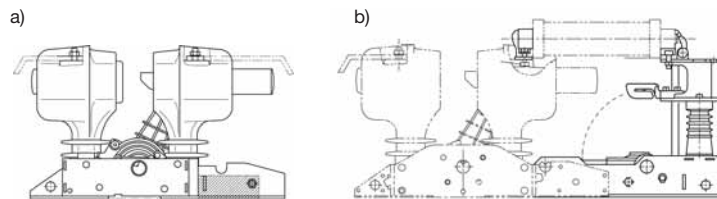


Fig. 8-3

C4 rod-type switch-disconnector:

a) without fuse assembly b) with fuse assembly

Knife-contact switch-disconnectors as per figure 8-2 and rod-type switch-disconnectors as shown in figure 8-3 are actuated in two ways, depending on their type:

a) "Snap-action mechanism", also referred to as toggle-spring mechanism. With this type of operating mechanism, a spring is tensioned and released shortly before the operating angle is completed and its release force actuates the main contact systems. This is used for both closing and opening.

b) "Stored-energy mechanism". This mechanism has one spring for closing and a second spring for opening. During the closing operation, the opening spring is simultaneously tensioned and latched. The stored energy for the opening operation is released by magnetic trips or the striker pin of the HRC fuse.

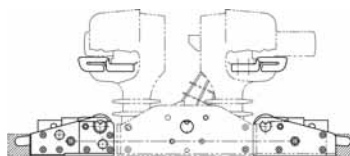
The rod-type switch-disconnector is particularly suitable for the design of compact switchgears, because the knife-contact switch-disconnector requires a greater depth for the switching zone because of the projecting contact blade in its open state. The rod-type switch-disconnectors also enable very small phase spacings without phase barriers.

8.1.3 Earthing switches

Earthing switches are installed in switchgears primarily near cable sealing ends, i.e. before the main switching device. However, earthing switches are often specified also for busbar earthing, for example in metering panels. If the main switching device is a switch-disconnector, the earthing switch and the switch-disconnector will often be on a common base frame (Fig. 8-4).

Fig. 8-4

Arrangement of earthing switches on a switch-disconnector base frame



Every earthing switch must be capable of conducting its rated short-time current without damage. "Make-proof" earthing switches are also capable of making the associated peak current at rated voltage. For safety reasons, make-proof earthing switches are recommended with air-insulated switchgear because of possible faulty actuations (DIN VDE 0101, Section 4.4). In gas-insulated switchgear, the earthing of a feeder is often prepared by the earthing switch and completed by closing the circuit-breaker. In this case, a separate make-proof earthing switch is not required.

8.1.4 Recognizable switch position

Because disconnectors, switch-disconnectors and earthing switches are very important to safety in the isolation of cables, lines and station components, there are special requirements for their position indication. It is true that the switch contacts themselves no longer need to be directly visible, but it is required that the switch position be recognizable, i.e. that actuation of indicators or auxiliary switches must be picked up directly at the switch contacts and not from a link in the force transmission mechanism upstream from the operating spring (IEC 62271-102 (VDE 0671 Part 102)).

8.1.5 HRC fuse links (DIN VDE 0670 Part 4)

The load current flows in fuse links through narrow melt-out conductor bands, which are arranged spirally in a sealed dry quartz sand filling in the interior of an extremely thermally resistant ceramic pipe. The conductor bands are designed with a narrower cross-section at many points to ensure that in the event of an overcurrent or short-circuit current, a defined melting will occur at many points simultaneously. The resulting arc voltage ensures current limiting interruption in case of high short-circuit currents.

Fig. 8-5
Fuse base with fuse link



The cap-shaped end contacts of the HRC fuse link are picked up by the terminal contacts of the fuse base. HRC fuse links can be fitted with indicators or striker pins, which respond when the band-shaped conductors melt through. The striker pin is required for mechanical tripping of the switching device when used in the switch/fuse combination (IEC 62 271-105 (VDE 0671 Part 105)).

Characteristic current values for HRC fuse links:

Rated current

The majority of fuse links in operation have a rated current < 100 A. For special applications with smaller service voltages (e.g. 12 kV), fuse links up to 315 A are available. The associated melt-through times of the fusible conductors can be found in the melting characteristics published by the manufacturers (Fig. 8-6).

Rated maximum breaking current

This value must be provided by the manufacturer of the fuse link. It is influenced by the design for a specified rated current. When selecting fuse links for transformer protection in distribution systems, the maximum breaking current is not a critical quantity.

Rated minimum breaking current

Classification of fuse links into three categories

– Back-up fuses

Smallest breaking current (manufacturer's information) in general at 2.5 to 3.5 times rated current. Suitable for application in switch/fuse combinations. Very common!

– General purpose fuses

The smallest breaking current is that which results in melt-through after 1 hour or more of exposure time (generally twice the rated current).

– Full-range fuses

Every current that results in a melt-through can be interrupted.

Cut-off current characteristic

The maximum value of the current let-through by the fuse depends on its rated current and the prospective short-circuit current of the system at the point of installation. Fig. 8-7 shows a characteristic field.

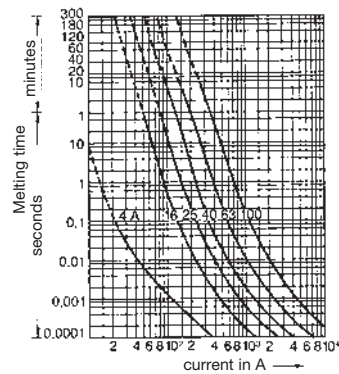


Fig. 8-6
Melting time in relation to overcurrent / short-circuit current

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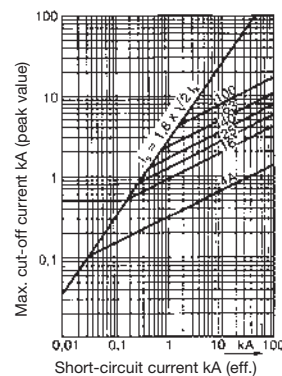


Fig. 8-7
Cut-off current in relation to short-circuit current

Selecting fuse links for specific conditions

When protecting transformers and capacitors with fuses, the inrush currents must be taken into account. When protecting transformers, selectivity is required by making the melting times of low-voltage fuses and HRC fuses match to ensure that the low-voltage fuses respond first.

In capacitor banks the rated current of the HRC fuse links should be at least 1.6 times the rated current of the capacitors. Experience has demonstrated that this covers also the influences of possible system harmonics and increased voltage.

When selecting fuse links for protection of high-voltage motors, the starting current and the starting time of the motors must be taken into account. The frequency of start-ups must also not be neglected, if this is frequent enough to prevent the fuses from cooling down between starts.

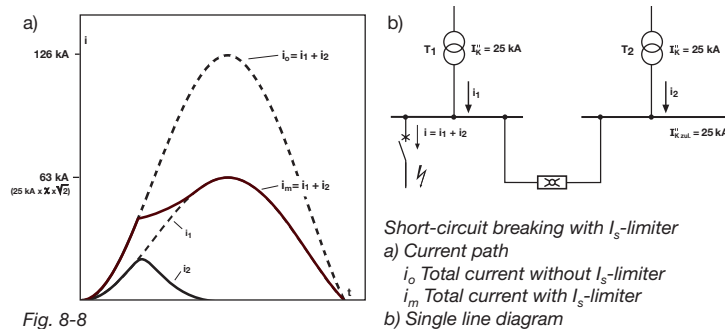
8.1.6 I_s -Limiter® – the world's fastest switching device

The increasing requirements for energy throughout the world demand higher rated or supplementary transformers and generators and tighter integration of the supply systems. This can also result in the permissible short-circuit currents of the equipment being exceeded and the equipment being dynamically or thermally destroyed.

It is often not technically possible or not economical for the user to replace switchgear and cable connections with new equipment with increased short-circuit current capability. The implementation of I_s -limiters when expanding existing installations and constructing new installations reduces the possible short-circuit current and costs.

A circuit-breaker does not provide protection against impermissibly high peak short-circuit currents, because it trips too slowly. Only the I_s -limiter is capable of detecting and limiting a short-circuit current in the initial rise, i.e. in less than one millisecond. The maximum instantaneous current value that occurs remains well below the peak value of the short-circuit current of the system.

The I_s -limiter, like a fuse, is therefore a current-limiting switching device, which detects and limits the short-circuit current in the initial rise (figure 8-8). The short-circuit current through the I_s -limiter is limited so quickly that it does not contribute in any way to the peak value of the short-circuit current at the fault location.



In principle, the I_s -limiter consists of an extremely fast switching device that can conduct a high rated current but has only a low switching capacity, and a parallel configured fuse with high breaking capacity (figure 8-9). To achieve the desired short switching delay, a small charge is used as energy storage to interrupt the main conductor. When the explosive charge has detonated, the current commutates to the parallel fuse, where it is limited within 0.5 ms and then is finally interrupted at the next voltage zero.

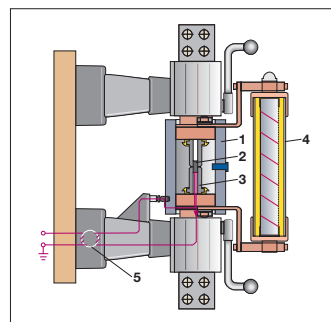


Fig. 8-9
Holder and insert of an I_s -limiter
1 Insulating tube
2 Charge
3 Bursting bridge (main conductor)
4 Fuse
5 Pulse transformer

Depending on the voltage, the rated currents of I_s -limiter inserts range up to 4,000 A (and even up to 4,500 A at 0.75 kV) and they can be connected in parallel for higher current levels.

I_s -limiters are most commonly used (figure 8-10)

- in couplings,
- in connections between the public network and internal power supply systems
- in parallel with reactors,
(avoidance of copper losses and voltage drops at reactors)
- in transformer or generator feeders, and
- in outgoing feeder panels.

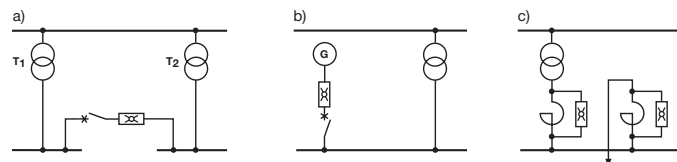


Fig. 8-10

Example applications of I_s -limiters

a) couplings, b) feeders, c) parallel circuits to reactors in incoming and outgoing feeders

8.1.7 Circuit-breakers

There are still a number of "small-oil-volume" circuit-breakers in use for rated voltages up to 52 kV in systems, but for new installations only vacuum or SF₆ circuit-breakers are used.

Circuit-breakers can be stationary mounted or integrated into the panel in withdrawable unit design with appropriate interlocking mechanisms.

Circuit-breakers must be capable of making and breaking all short-circuit and service currents occurring at the operational site. See 10.4.3 for details. The testing conditions for the corresponding verifications can be found in DIN VDE 0671 Part 100.

Vacuum circuit-breakers

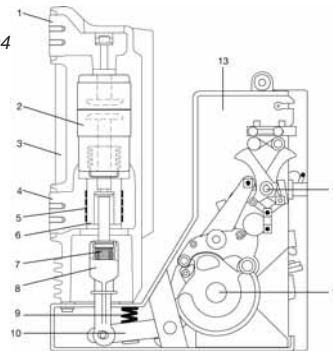
Vacuum circuit-breakers of the VD4 type are available from the ABB production range for short-circuit breaking currents up to 63 kA with rated currents from 400 to 4,000 A. The VD4 range covers the voltage ranges of 12 kV, 17.5 kV, 24 kV and 36/40.5 kV.

Fig. 8-11 shows a vacuum circuit-breaker of the VD4 type in column design.

Fig. 8-11

Section of a vacuum circuit-breaker type VD4 for 12 kV, 2,000 A, 40 kA

- 1 Upper terminal
- 2 Vacuum interrupter
- 3 Cast resin enclosure
- 4 Lower terminal
- 5 Multi-contact
- 6 Piston
- 7 Contact pressure spring
- 8 Insulated actuating rod
- 9 Opening spring
- 10 Guide lever
- 11 Mechanism shaft
- 12 Release mechanism
- 13 Mechanism enclosure with stored-energy spring mechanism



The components of the main current path (upper breaker terminal, vacuum interrupter, lower terminal, etc.) are embedded in cast resin and thus completely enclosed by insulating material. The concept of these embedded pole parts, in which the vacuum interrupter forms a positive and non-positive unit with the entire pole, precludes disruptive external influences on the switching element proper. The VD4 vacuum circuit-breaker is therefore particularly suitable for construction of compact panels.

Figure 8-12 shows the VD4 circuit-breaker with isolating contact arms on the withdrawable module frame for service in air-insulated panels of type UniGear ZS1.

Fig. 8-12
Vacuum circuit-breaker type VD4 for 12 kV as a withdrawable unit

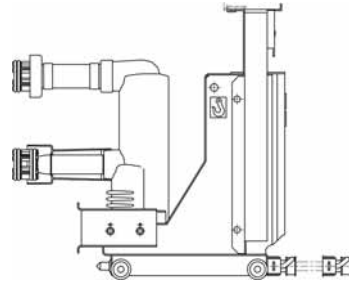
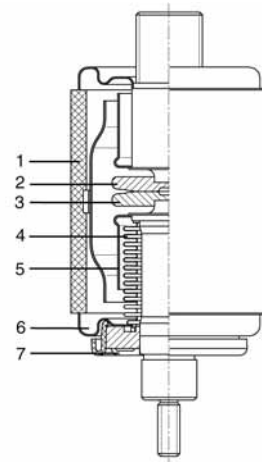


Fig. 8-13 shows the most important components of a vacuum interrupter from the ABB range in sectional view. All joints of the conducting path and of the external enclosure are manufactured by brazing in vacuum furnaces with the aid of special hard solder. This results in an extremely reliable and long-lasting seal.

Fig. 8-13
Partial section of a vacuum interrupter, simplified schematic illustration

- 1 Insulator
- 2 Fixed contact
- 3 Moving contact
- 4 Metal bellows
- 5 Screen
- 6 Interrupter lid
- 7 Anti-rotation element



The contacts are a copper/chromium composite material, a copper base containing evenly distributed fine-grained chromium particles, which has a good extinguishing and arc-resistant response when switching short-circuit currents, and is also distinguished by low-chopping current values when breaking small inductive currents.

Switching overvoltages

Switching overvoltages when switching inductive loads with vacuum circuit-breakers have long been a subject of discussion. The introduction of copper/chromium as the contact material has significantly reduced the occurrence of hazardous overvoltage levels. To cover the residual risk, surge arresters based on metal oxide (MO) are recommended for certain applications. Examples of such applications are:

- small motors (with starting current below about 600 A),
- small generators,
- reactor coils for power factor correction,
- dry-type transformers in industrial applications.

Only in special cases (e.g. furnace transformers) are supplementary RC circuits required, preferably in the form of ZORC combinations (zinc oxide+R+C).

Actuating systems

The travel of the moving contact between the open and closed positions in the vacuum circuit-breaker is between 8 and 14 mm depending on the rated voltage. At the end of the closing stroke, the energy for tensioning the contact pressure springs is required. The relatively low total energy requirement for vacuum circuit-breakers is generally provided by mechanical spring stored energy operating mechanisms, as with the VD4 type. Tripping is initiated by magnetic releases or manually. The mechanical operating mechanism of the VD4 circuit-breaker is always suitable for autoreclosing (0 – t – CO).

Figure 8-14 shows a new operating mechanism system for the vacuum circuit-breaker of type VM1.

- 1 Upper terminal
- 2 Vacuum interrupter
- 3 Cast resin enclosure
- 4 Lower terminal
- 5 Flexible connector
- 6 Contact pressure spring
- 7 Insulated actuating rod
- 8 Lever shaft
- 9 Sensor for switch position ON
- 10 Sensor for switch position OFF
- 11 ON coil
- 12 Permanent magnets
- 13 Magnet armature
- 14 OFF coil
- 15 Emergency manual switch-off
- 16 Mechanism enclosure

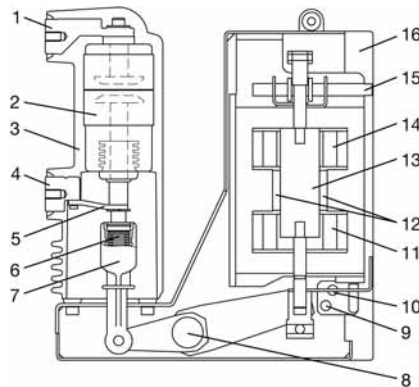


Fig. 8-14

Vacuum circuit-breaker type VM1 with magnetic actuator (compatible with type VD4)

The movable contacts here are actuated by a permanent magnet mechanism with two stable limit positions. The contact movements are initiated by current pulses to one coil for each contact (approx. 100 Watt / 45 ms), generated by discharge of a capacitor, i.e. with less energy than with the magnetic releases of the stored-energy spring mechanism.

The release currents are exclusively controlled by electronic components (thyristors and transistors). A fixed-programmed logic circuit coordinates the processes and interlock conditions. The contact position is detected by sensors. The interface to the automation system is through binary inputs and outputs.

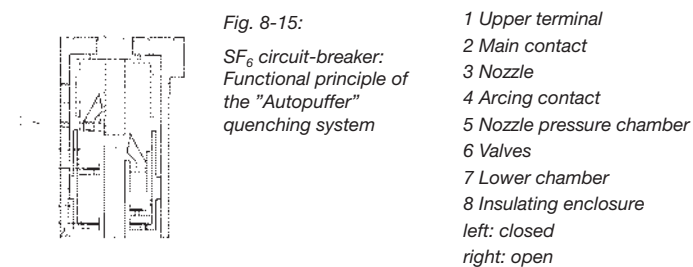
Because of the extremely small number of individual parts, this actuating system offers significant advantages in reliability, durability (up to 100,000 switching cycles) and manufacturing costs.

The pole section (figure 8-14) with the vacuum interrupter moulded in epoxy resin has optimum dielectric properties, permanent protection against external influences of all types and because of the small number of parts, very little likelihood of faults occurring. This eliminates the requirement for maintenance of this switching device under standard operating conditions.

SF₆-circuit-breakers

After its successful implementation in the range of transmission voltages (cf. section 10), SF₆ has also become established in the medium-voltage range. The puffer type arc-quenching principle, which was introduced first, provides an effective arc-quenching gas flow by a mechanically driven piston. However, this requires high energy driving systems. Hence self-blast arc-quenching systems of different types were developed, where the relative movement between the gas and the arc is provided by the arc itself.

The ABB SF₆ circuit-breakers of type HD4 make use of a combination of these two different arc-quenching principles (see figure 8-15). They cover the voltage range up to 24 kV, with short-circuit breaking currents up to 50 kA and service currents up to 4,000 A. The arc-quenching system applies the gas compressed in the lower chamber to interrupt small currents with overvoltage factors < 2.5 p.u. even in the case of small inductive currents. High short-circuit currents are interrupted by the self-blast effect applying the pressure built up in the moving chamber by the arc energy.

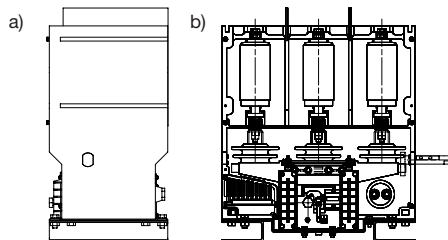


8.1.8 Vacuum contactors

Vacuum contactors, in connection with HRC fuses, are particularly suitable for operational switching of motors with very high switching frequency, e.g. medium voltage motors for pumps, fans, compensators and capacitors. HRC fuses provide protection for cables and circuit components in case of a short circuit. Vacuum contactors have a life expectancy (electrical) of $1 \cdot 10^6$ operating cycles, and can handle a switching frequency up to 1,200 on/off operations per hour. The vacuum contactors of type VSC (figure 8-16) have rated voltages of 3.6 to 12 kV and a rated current of 400 A, and are suitable for switching of motors with ratings of 1,500 (3.6 kV) to 5,000 kW (12 kV), and capacitors from 1,500 to 4,800 kVar. This does not however take account of whether suitable fuses are available to take advantage of the listed performance ranges.

Fig. 8-16

Vacuum contactor, type VSC, with magnetic actuator
a) Front view
b) Sectional view



8

8.2 Switchgear installations (≤ 52 kV)

8.2.1 Specifications for switchgear installations

This voltage range – generally referred to as medium voltage – covers switchgears and controlgears in use and on the market that can be classified as per one of the two following standards:

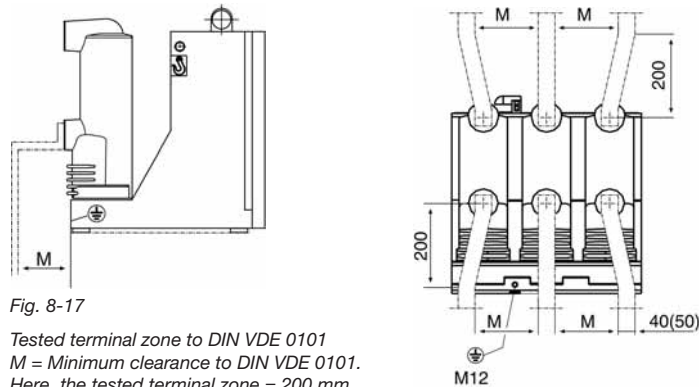
DIN VDE 0101 or
IEC 62271-200 (VDE 0671 Part 200)

8.2.2 Switchgear and controlgear DIN VDE 0101

Switchgears and controlgears to DIN VDE 0101 are designed to comply with fixed minimum clearances of live components from one another, from earth potential and from protecting barriers. They can basically be manufactured at the site where they will be operated. Current-carrying capacity for service and short-circuit currents must be verified by calculation (see also section 4). Type testing is not required.

When setting up these installations in electrical equipment rooms with restricted accessibility, protection against accidental contact with live components, e.g. screens or rails, is sufficient. The switchgear can also be designed with sheet metal walls and doors (minimum height 180 cm) (cf. sections 4.5; 4.6 and 5.2). Reinforced wallboard is also frequently encountered as a wall material. The switchgears can also be completely enclosed for full protection for operation outside locked premises.

The use of insulating materials and intelligent design will allow smaller clearances, particularly in the terminal zone of circuit-breakers and switch-disconnectors, than the specified minimum clearances as per DIN VDE 0101 (cf. Table 4-12). A device of this kind must be tested with connected conductors in the zone in which the permissible minimum clearances are not met. This zone is referred to as the "tested terminal zone" (see DIN VDE 0101). It must be included in the user's manual for the switching devices with the main dimensions (figure 8-17).



Today, switchgears and controlgears to DIN VDE 0101 are mainly encountered in individual installation design on site or are manufactured by smaller companies without in-house test laboratories.

DIN VDE 0101 also includes basic specifications for the general design of a substation, including the structural requirements. They are also applicable for the installation of type-tested switchgear as per IEC 62271-200 (VDE 0671 Part 200).

8.2.3 Metal-enclosed switchgear and controlgear to IEC 62271-200 (VDE 0671 Part 200)

Metal-enclosed switchgear and controlgear are generally assembled from type-tested panels these days. As per IEC 62271-200 (VDE 0671 Part 200) metal-enclosed switchgear installations must be designed so that their insulation capacity, degree of protection, current carrying capacity, switching capacity and mechanical function conform to the requirements set by the testing provisions. This is verified by a type test on a prototype panel. In addition, a routine test is made on every completed panel or every transport unit.

Note: Together with IEC 62271-200 (VDE 0671 Part 200), the higher-order standard IEC 60694 (VDE 0670 Part 1000) is always to be observed. Type-tested switchgear installations with insulated enclosures are subject to IEC 60466. However, there is no longer a corresponding European or German standard.

Rated voltage

The rated values for the insulation level of a switchgear installation must be selected on the basis of the requirements of the system at the installation site from the selection tables in IEC 60 694 (VDE 0670 Part 1000).

Table 10-1 (Section 10) shows the selection values for the range of rated voltages up to 52 kV. The voltage values "over the isolating distance" only apply for switching devices with which the safety requirements for the open contacts of disconnectors must be met.

Table 10-1 lists two value pairs that can be selected for the rated lightning impulse voltage level for almost all rated voltages. The options correspond to the former subdivision in list 1 and list 2.

When making the selection, the degree of danger from lightning and switching overvoltages, the type of neutral treatment and, if applicable, the type of overvoltage protection should be considered. The higher value pairs in each case are the ones to be selected for installations and equipment exposed to atmospheric overvoltages, e.g. by direct connection to overhead lines. The lower value pairs can be used for installations that are not exposed to atmospheric overvoltages or are protected from these overvoltages by arresters.

Insulating media

IEC 62271-200 covers both switchgear in which atmospheric air acts as the gaseous insulation within the enclosures and also switchgear in which an insulating medium in the form of a fluid other than the atmospheric air (e.g. SF₆) is used (air-insulated: AIS/gas-insulated: GIS).

Degree of protection for metal-enclosed switchgear and controlgear

The metallic and earthed enclosure protects personnel against approach to live components and against contact with moving parts. It also protects the installation against the penetration of foreign bodies. One of three different degrees of protection may be selected for switchgear to IEC 62271-200. The difference is whether the enclosure is suitable for repelling fingers or similar objects (IP 2X to IEC 60694, Minimum requirements for metal-enclosed switchgear), rigid wires more than 2.5 mm in diameter (IP 3X) or rigid wires more than 1 mm in diameter (IP 4X).

Compartments, accessibility and service continuity

Within the general term "metal-enclosed", distinctions were formerly made between three categories – "metal-clad", "compartmented" and "cubicle" switchgear – depending on the design of the internal compartmentalization. This structural definition of compartmentalization has now been replaced in IEC 62271-200 by classification according to the accessibility of the compartment with high voltage components. Three of four classes are determined by how access is controlled, and whether it is necessary to open the compartment in normal operation or only for maintenance. Opening of all compartments which are only accessible by means of tools is not part of normal operation. The fourth class describes non-accessible compartments, such as those found in gas-insulated switchgear.

With a view to the accessibility of the compartments, the following distinctions are made:

- "Interlock-controlled accessible compartment"
Integral interlocks enable access to open the compartment for normal operation and/or maintenance.
- "Procedure-based accessible compartment"
Access to open the compartment for normal operation and/or maintenance is regulated by a suitable procedure combined with locking.
- "Tool-based accessible compartment"
The compartment can be opened with tools, but not for normal operation and/or maintenance.
- "Non-accessible compartment"

Categorization is then determined by the loss of service continuity, focusing on the main switching device. The LSC categories result from the scope of switchgear components to be taken out of service when a compartment is opened:

- LSC 1:
This category covers the lowest level of service continuity. It applies to an accessible compartment in a panel which would require at least one further panel to be taken out of service when it is opened. If a busbar compartment is opened, all the panels in the relevant section must be de-energized.
- LSC 2A:
Category 2A stands for a panel which has to be taken completely out of service when a compartment is opened. The panel has partition walls separating it from the adjacent panels and at least two compartments and an isolating distance.
- LSC 2B:
Category 2B provides the least restriction to service continuity and means that all other panels in the installation and all cable termination compartments (including that in the panel concerned) remain in operation when a compartment is opened. It requires partition walls to the adjacent panels and at least three compartments and two isolating distances per panel.

When a compartment has been opened, partitions and shutters to the adjacent compartment or panel provide a degree of protection against live high voltage components. The "partition class" indicates whether the partition is metallic throughout or contains parts of insulating material.

- Class PM:
"Partition of metal"; metallic shutters and partitions between live parts and an open compartment.
- Class PI:
"Partition of insulating material"; discontinuity in the metallic partition/shutter between live parts and an open compartment, which is covered by insulating material.

Both partition classes provide the same protection against accidental contact for the worker, but a metallic partition also screens off the electric field.

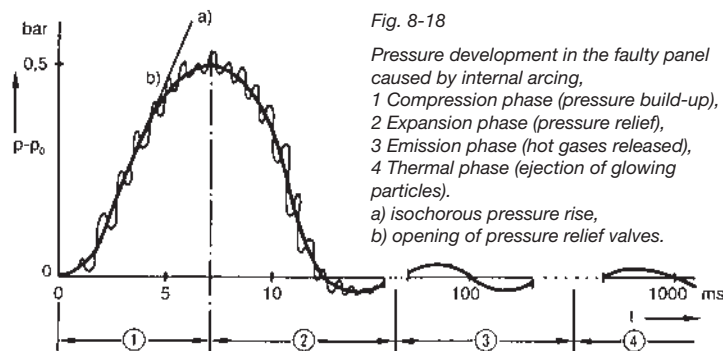
The decision on which of these installation categories is to be used in any specific case is up to the user, with most attention paid to safety of personnel during maintenance and cable work inside the metal-enclosed switchgear and controlgear. Restricting the effects of faults is important only when the resistance of the compartment walls to arcing has been verified and when the compartmentalization forms a true potential separation (class PM).

Internal arcing

All specialists are in basic agreement that manufacturers and users must make every effort to prevent under all circumstances faults in switchgear installations in which internal arcing occurs. However, it is also acknowledged that such faults cannot be completely prevented in all cases. For this reason, it is expected that current switchgear designs have been tested for response to internal arcing.

Internal short-circuit arcs during operation can occur by overvoltage, faulty insulation or improper control. The test consists of inducing the arc with an ignition wire connected over all three phases. The arc has temperatures of around 4.000 K in the area of its footing points and around 10.000 K or more in the area of the arc column. Immediately after the arc has been ignited, the gas in the immediate vicinity of the arc heats up instantly, causing a very steep rise in pressure in the compartment concerned. This pressure increase would continue to the load limit of the enclosure if pressure relief vents were not built into it. The sealing covers or membranes of these vents respond in ca. 5 to 15 ms and open the path to allow the heated gases to vent (figure 8-18). This characteristic process is not determined only by the response time of the pressure relief valves but it also results from the mechanical inertia of the heated gas mass.

The maximum pressure reached is dependent on the volume of the compartment where the fault occurs and on the magnitude of the short-circuit current. The greatest quantity of heated gases is given off into the area around the switchgear during the expansion phase. The pressure stress on the panel exceeds its high point as early as about 15 ms, that of the building has reached its maximum stress after around 40 ms. A powerful ejection of still heated gases of low density and glowing particles occurs in the subsequent emission phase and in the thermal phase.



Guidelines for testing metal-enclosed switchgear for its response to internal arcing can be found in Appendix A of IEC 62271-200 (VDE 0671 Part 200).

The specified test conditions require the internal arcing to be ignited with a thin ignition wire in each compartment of the panel to be tested. The point of ignition and the direction of energy flow are specified in such a way that the arc burns as long as possible at the most distant location from the feeder. The short-circuit test plant supplying the test object, which consists of at least two panels, must have sufficient power to allow a short-circuit current as high as the rated short-time withstand current to flow in three phases over the internal arcing during the agreed duration of the test (recommended times 1.0, 0.5 or 0.1 s). This will cover the normal protection grading times at full short-circuit current. With this short-circuit duration, the test result is restricted to the question of whether the tested compartment withstands the stress caused by the internal overpressure.

During the test, fabric indicators (black, cretonne or cotton-wool batiste) are stretched vertically at a defined spacing on metal frames in front of the accessible walls of the panels and horizontally at 2 m height above the zone where personnel would be when operating the installation. With metal-enclosed switchgear, a distinction is made between two degrees of accessibility which are possible at the point of installation:

Accessibility type A: For authorized personnel only

Accessibility type B: Unlimited access for the general public

The test conditions are also defined in accordance with these accessibility types (figure 8-19). Different sides of a switchgear installation can have different degrees of accessibility. The identification code for these uses the letters F (front), L (lateral) or R (rear).

Accessibility – Type A		Accessibility – Type B	
$h > 2 \text{ m}$	$h < 2 \text{ m}$	$h \leq 2 \text{ m}$	$h < 2 \text{ m}$

Fig. 8-19

Arrangement of the indicators for an arc fault test
 h = height of switchgear; i = arrangement of indicators

On completion of the short-circuit test, the behaviour of the tested panels is recorded on the basis of five criteria:

- Criterion 1:
Doors and covers remain closed. Deformations are acceptable if no part reaches the indicators or walls.
- Criterion 2:
No fragmentation of the enclosure occurs within the duration of the test. Projections of small parts, up to an individual mass of 60 g, are acceptable.
- Criterion 3:
Arcing does not cause holes in the accessible outer sides of the enclosure up to a height of 2 m
- Criterion 4:
Horizontal and vertical indicators must not be ignited by hot gases. Permitted exceptions: ignition by burning paint coatings, stickers or glowing particles.
- Criterion 5:
Earth connections remain effective, as demonstrated by visual inspection.

Additional information can be obtained in the form of high-speed camera pictures or videos taken during the test, and these are therefore highly recommended.

If the arc fault test is passed, for instance in the context of a type test, this is documented by the designation IAC ("Internal Arc Classified") on the type plate. The confirmation of testing is supplemented by additional data such as the accessibility type, indications of the accessible sides, the test current and duration.

There are further points to be considered over and above criterion 5 of the assessment, as in the event of ejection of hot gases, the switchgear and controlgear itself is not primarily relevant for the effects. Reflection from the ceilings and walls in the emission phase and the thermal phase (figure 8-18) can divert the hot gases coming from the pressure relief vents into zones accessible for personnel and cause hazardous conditions there. The highest degree of damage also occurs during this period inside the switchgear and controlgear. The ejection of very hot gas reaches its most hazardous amount under the condition when caused by the direction of supply (from below) the electromagnetic forces compel the arc to persist in the immediate vicinity of the pressure relief vent. A panel type may be considered fully tested only after this case has been considered.

Countermeasures for protection of the operating personnel against these effects can be as simple as installing screens or discharge plates. At high short-circuit currents, hot gas conduits with blow-out facilities using absorbers discharging into the switchgear installation room are the perfect solution. However, even better results without additional installations can be achieved if it is possible to limit the arc duration to approximately 100 ms by appropriate trip times. Because the grading times of the system protection do not generally allow such a short-term tripping of the feeder circuit-breaker, additional sensors are required, such as the I_{th} -limiter. When one of the pressure relief valves opens and there is simultaneous persistent short-circuit current, it initiates an undelayed trip command to the feeder circuit-breaker. This quenches the internal arc in less than 100 ms.

The pressure load on walls, ceilings, doors and windows of the switchgear installation room is the result of the gas ejection during the expansion phase (figure 8-18). The withstand capability can generally not be verified by testing. All major manufacturers provide calculation programs for determining the pressure development in the switchgear installation compartment to find out whether pressure relief vents are required for the installation room.

8.2.4 Metal-enclosed air-insulated switchgear and controlgear to IEC 62271-200 (VDE 0671 Part 200)

Switchgear of this type currently has the largest market share worldwide

Metal-enclosed switchgear with three compartments

Figure 8-20 shows an example of such a metal-enclosed panel of type UniGear ZS1 to LSC category 2B and partition class PM.

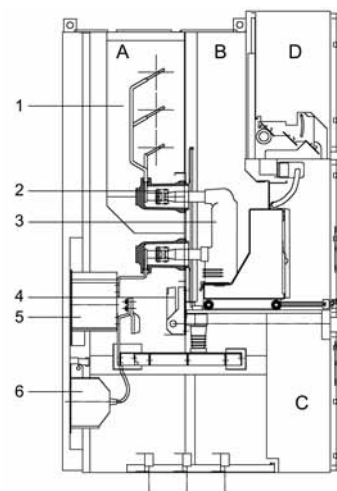


Fig. 8-20

- A Busbar compartment
- B Main switching device compartment
- C Cable termination compartment
- D Low voltage compartment
- 1 Busbar
- 2 Isolating contacts
- 3 Circuit-breaker
- 4 Earthing switch
- 5 Current transformer
- 6 Voltage transformer

The circuit-breaker of this type of switchgear can be moved between the operating position and test position when the door is closed. Because vacuum circuit-breakers under normal operating conditions are almost maintenance-free, the door to the circuit-breaker compartment can remain permanently closed. However, if it should be necessary to remove the breaker from the panel, this can be done without problems on a service truck that can be adjusted for height to the exact position.

Access to the cable sealing ends can be made much easier by removing the circuit-breaker and also removing the partition between compartments B and C.

Compartment C has room for the sealing ends of several parallel cables. Metallic oxide arresters for overvoltage protection of inductive loads can also be installed here.

When the circuit-breaker is in the test position and the panel doors are closed, the cables can be earthed via the permanently installed earthing switch (4, with short-circuit making capacity). In order to check that the cables are off-circuit, voltage indicator plugs can be inserted into test sockets at the front of the panels. The test sockets are connected to the terminals of capacitive dividers, which are integrated in the current transformers.

Instead of the vacuum circuit-breaker, an SF₆ circuit-breaker of the HD4 type with identical main dimensions can be installed in this switchgear type.

The UniGear ZS1 panel shown in figure 8-20 is designed for rated voltages up to 24 kV, rated currents up to 4,000 A and rated short-time currents (3s) up to 50 kA. For 12 and 17.5 kV, the panel dimensions range between widths of 650/800/1000 mm and depths of 1300/1350 mm, and for 24 kV between 800/1000 mm and 1500 mm respectively. The uniform height is 2200 mm.

In addition to the standard switchgear panels with withdrawable circuit-breakers, there are variations for sectionalizers, metering panels and panels with permanently installed switch-disconnectors for substation power supply transformers. A further type provides for the use of vacuum contactors. Figure 8-21 shows a sectional view of such a contactor panel of type ZVC. One advantage of this panel is the small width of only 325 mm. Short-circuit protection is performed here by an HRC fuse integrated in the contactor module. Double busbar installations are constructed from single busbar panels in accordance with the two circuit-breaker method in back-to-back or front-to-front configurations (figure 8-22 with panel type UniGear ZS1). One highly interesting variant for constricted spaces is the opportunity to accommodate two circuit-breakers

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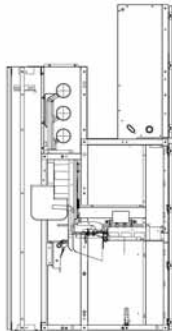


Fig. 8-21
Panel type ZVC with vacuum contactor on withdrawable part

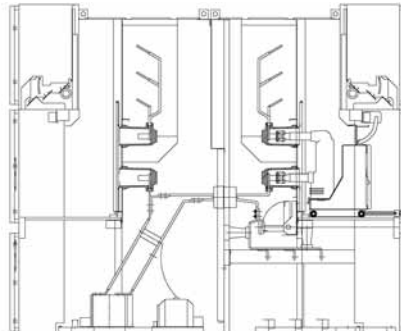


Fig. 8-22
Double busbar switchgear installation with UniGear type ZS1 panels in back-to-back configuration

on two levels in a UniGear Double Level Panel with a width of only 750 mm for 12 kV and up to 31.5 kA (900 mm for 50 kA) (figure 8-23).

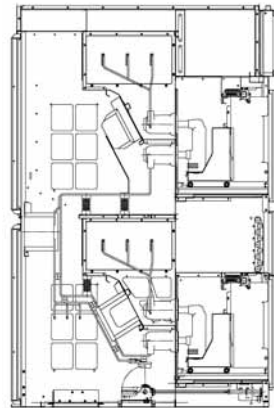


Fig. 8-23
Two level panel configuration of type
UniGear Double Level

Metal-enclosed switchgear with one or two compartments

Figure 8-24 shows metal-enclosed switchgear of type ZS8 with one compartment in accordance with LSC category 1 and partition class Pl. They are available as panels with permanently installed switch-disconnectors for switching cables and overhead lines and with HRC fuses for protection of distribution transformers. The switch-disconnectors can be remote-controlled by a motor-operated mechanism. In the circuit-breaker panels, the VD4 and VM1 vacuum circuit-breakers are withdrawable units that can be moved when the panel door is closed.

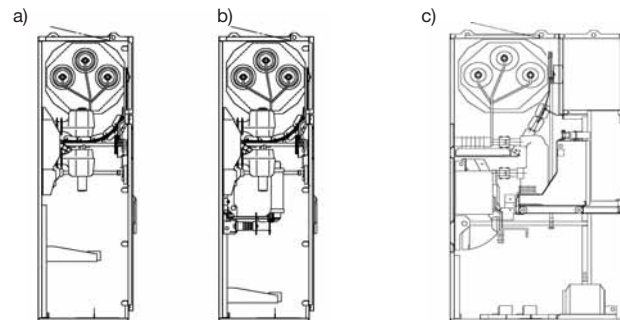


Fig. 8-24

Panels of type ZS8:

- a) Switch-disconnector panel
- b) Switch-disconnector panel with HRC fuses
- c) Circuit-breaker panel

All the panel variants in the ZS8 series can be mounted side by side in spite of their different dimensions. The switch-disconnector panel can however also be supplied in the same depth as the circuit-breaker panel. The most important dimensions of these panels are widths of 600 or 650 mm for the switch-disconnector panel and 650 or 800 mm for the circuit-breaker panel. Depending on the ratings, the panel depths are 600/800/1000 or 1200 mm. The panel height is standardized at 1900 mm. The rated data cover a voltage range up to 24 kV, busbar currents and tee-off currents with circuit-breakers up to 1,250 A, tee-off currents with switch-disconnectors up to 630 A, and short-time currents (3s) up to 25 kA.

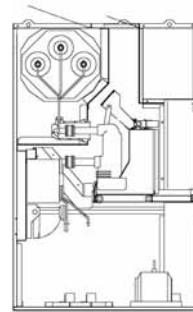
ZS8 panels are equipped with earthing switches (with short-circuit making capacity) for feeder earthing. The earthing switches can only be closed when the switch-disconnector is open or the circuit-breaker withdrawable unit is in the disconnected position. There is an insulating plate integrated in every panel, which slides into the open break of the switch-disconnector or in front of the busbar-side isolating contacts of the circuit-breaker panel. This assures protection against accidental approach to live components during work in the panel, e.g. at the cable sealing ends. There are also ZS8 panels with "tee-off partitions" to LSC category 2A and partition class PM (figure 8-25). These panels have earthed metallic partitions, which separate the busbar system from the areas of switching devices and cable terminals. The protection against accidental contact with the isolating contacts installed in epoxy resin spouts in these panels is provided by earthed metallic shutters that swing in front of the epoxy resin spouts. The panel doors can only be opened after closing the protection shutter in all ZS8 type switchgear.

Checking that the cables are off-circuit can be performed with conventional voltage indicators or by using voltage indicator plugs at externally accessible test sockets. Measurements using sockets require installation of capacitive divider devices in the epoxy resin insulators of the switch-disconnector or in the current transformer of the circuit-breaker panels.

Panel variations of the ZS8 series in addition to the switchgear with switch-disconnectors or circuit-breakers include sectionalizers, busbar risers and metering panels.

8

Fig. 8-25
Switchgear type ZS8 with tee-off partition



Here, too, there is a special design for the use of vacuum contactors. Figure 8-26 shows a sectional view of such a panel.

Double busbar switchgear can also be implemented in this system with ZS8 panels in a special back-to-back configuration (figure 8-27).

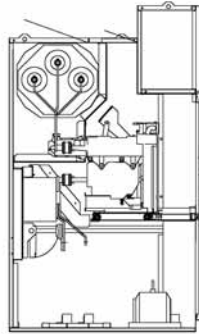


Fig. 8-26
ZS8 switchgear with contactor and HRC fuses on a withdrawable assembly

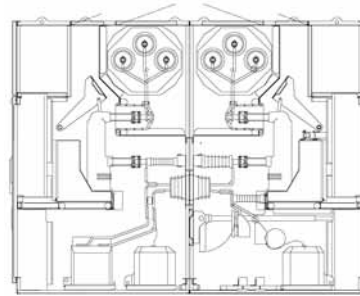


Fig. 8-27
Double busbar installation with ZS8 switchgear in back-to-back configuration

8.2.5 Metal-enclosed gas-insulated switchgear and controlgear

switchgear to IEC 62271-200 (VDE 0671 Part 200)

The same standard as for the air-insulated switchgear and controlgear described in section 8.2.4 also applies to the gas-insulated switchgear of the medium-voltage range. The term "gas-insulated" refers to the fact that atmospheric air is not used as the gaseous insulating material inside the panels, i.e. the enclosure of the installation must be gas-tight against the environment.

The gas currently used in most gas-insulated designs is a synthetic electronegative gas, SF₆, with almost three times the dielectric resistance of air. (See also section 16.3.) The insulating gas can also be nitrogen, helium or air dried for the purpose and at a higher pressure level.

The decisive advantage of gas-insulated switchgear compared to an air-insulated installation is its independence from environmental influences such as moisture, salt fog and pollution. This results in less maintenance, increased operational safety and high availability. The smaller dimensions due to compact design and increased dielectric resistance of the gaseous insulating material are also advantages. Gas-insulated switchgear technology in the medium-voltage range has become increasingly significant over the last 30 years.

The numerous designs available on the market can be generally classified into three different application groups:

- switchgear with circuit-breakers
- switchgear with switch-disconnectors and circuit-breakers
- ring-main units

One technical solution for each of these application groups is described below as an example.

Gas-insulated switchgear with circuit-breakers

Figure 8-28 shows a panel of type ZX1 (for 12 to 36 (40.5) kV) with the versatile options offered by the advanced technology of these new switchgear designs.

The principles used for the application are:

- High-precision enclosure
- The gas-tight enclosure of the live components is manufactured from stainless steel using laser technology for high-precision cutting and welding. This not only ensures that the enclosure is gas-tight but also allows the panels to be mounted side by side at site without problems.

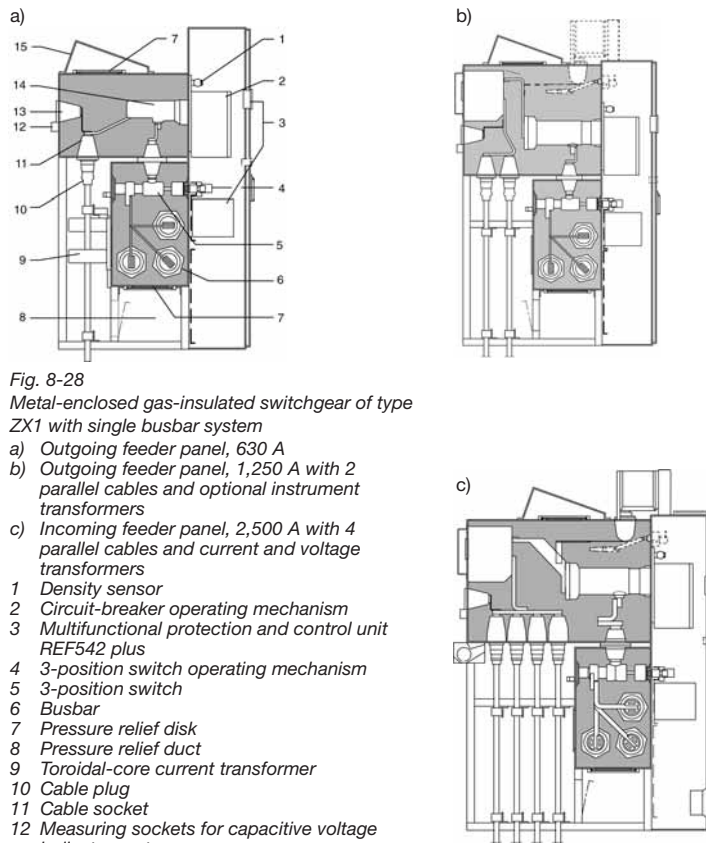


Fig. 8-28
Metal-enclosed gas-insulated switchgear of type ZX1 with single busbar system

- a) Outgoing feeder panel, 630 A
- b) Outgoing feeder panel, 1,250 A with 2 parallel cables and optional instrument transformers
- c) Incoming feeder panel, 2,500 A with 4 parallel cables and current and voltage transformers
- 1 Density sensor
- 2 Circuit-breaker operating mechanism
- 3 Multifunctional protection and control unit REF542 plus
- 4 3-position switch operating mechanism
- 5 3-position switch
- 6 Busbar
- 7 Pressure relief disk
- 8 Pressure relief duct
- 9 Toroidal-core current transformer
- 10 Cable plug
- 11 Cable socket
- 12 Measuring sockets for capacitive voltage indicator system
- 13 Test socket
- 14 Circuit-breaker
- 15 Plasma deflector
- SF_6

Vacuum switching technology

- The application of vacuum switching technology as the quenching principle of the circuit-breaker meets a primary requirement for gas-insulated switchgear: the interrupter unit must be maintenance-free. So far, this requirement is really only met by vacuum interrupters, because of their low contact burn-off and their high electrical durability. Gas-insulated switchgear for this voltage range with SF₆ circuit-breakers is however also available.

Plug connector technology

- The application of plug-in technology is essential for ensuring short assembly times when setting up installations. Several parallel cables can be connected to the commercially available internal conical sockets in the baseplate of the core module. The plug-in technology in the area of the busbar bushings is new but based on the same technology as the cable connectors. These bushings designed as plug connectors are the most important requirement for easy installation of the completed panels. There are additional plug connectors in the supply lines for auxiliary power and in the fibre-optic connections to the higher-order control system, if present.

Sensors for measured quantities and states

- The combined current/voltage sensor has three functions. For current measurement, it has a Rogowski coil, which gives a voltage signal that has a linear dependency on the current and therefore can be used in a very broad current range (e.g. to 1250 A in one type). This not only simplifies planning but also increases the flexibility when modifying installations that are already operating.
- A high-resistance (200 MΩ) voltage divider is used as a voltage sensor. Two bell-shaped screening electrodes ensure equal distribution of the electric field along the resistance. The voltage signal captured at the subresistance of the divider is fed to the bay control unit.
- The earth side of the two screening electrodes is simultaneously used as a capacitive pick-off for voltage indication with standard commercial plugs. It is connected to test sockets on the front of the panel to allow checking that the cables are off-circuit independently of the functional availability of the bay control unit.
- The positions of the two switching devices and the 'ready for switching' indication of the circuit-breaker mechanism are detected by inductive proximity sensors. A temperature-compensated pressure sensor signals three pressure/density levels: filling pressure at 20°C, lower operational pressure limit and pressure with internal arcing. All sensor information goes directly to the bay control unit and is displayed and processed there.

Digital bay control and protection unit

- The multifunctional bay control and protection unit REF542 plus is the base of the intelligence and communications interface of the new switchgear (see also section 14).

It has the following functions:

- Local and remote actuation
- Display of switch positions, measured values and protection parameters
- Interlocking, internal and external

- Protection (all protective functions except for differential cable protection)
- Storage of events
- Information transmission to a higher-order control system
- Monitoring its own functions and the release and measurement circuits
- Disturbance recorder – recording time 5 s with sampling rate 1.2 kHz

Faults in the sequence of actuation of circuit-breaker and disconnect/earthing switch function of the transfer switch are prevented by interlocking in the control unit. The earthing process can be automatically run as a programmed sequence while retaining the "five rules of safety". Any required protective functions can be installed as software before delivery. Software changes can be made on site at any time with a laptop computer. Parameter changes can be made by pressing buttons on the device itself.

Personnel safety design

In a switchgear system such as that of the ZX1 family, the occurrence of faults with internal arcing is unlikely from the start. However, ZX1 panels offer complete personnel protection in the event of internal arcing. In the case of a fault in the area of the insulating gas, the housing is relieved from excessive stress by the response of the pressure relief diaphragm, either directly into the switchgear room via the plasma absorber or into a pressure release duct which runs horizontally across all the panels and at the end of the installation releases the gas into the open air through an outside wall or into the switchgear installation room via an absorber. The response of the pressure sensor at 0.6 bar overpressure can be used to trip the feeder circuit-breaker immediately without requiring additional components, thereby reducing the arcing time to less than 100 ms. In the event of a fault in the cable plug area, the pressure is also relieved into the pressure relief duct.

Here too, double busbar switchgear installations can be designed with the panels of type ZX1, in accordance with the two-circuit-breaker method in back-to-back or front-to-front arrangement. Panel variants such as sectionalizers, busbar risers and metering panels are also available.

The most important ratings are as follows: Rated voltage up to 36 (40.5) kV, rated current up to 2,500 A and rated short-time current (3 s) up to 31.5 kA. The panel width is 600 or 800 mm, depending on the current, the depth varies from 1300 to 1800 mm depending on the cables connected, and the height is 2100 mm. The insulating gas is SF₆ at a rated filling pressure of 130 kPa.

The switchgear of type ZX2 (figure 8-29) is suitable for "conventional" double busbar systems that have two busbar systems for each panel. This switchgear has the same advanced features as described for switchgear of type ZX1.

The technical data implemented to date include the rated voltage of up to 36 (40.5) kV, rated current up to 2,500 A and rated short-time current (3 s) up to 40 kA. Here too, the panel width is 600 or 800 mm, depending on the current, the depth is 1760 mm and the height is 2300 mm. The insulating gas is SF₆ at a rated filling pressure of 130 kPa.

Single busbar switchgear in the ZX2 design can also be used without the rear busbar system to make full use of the advanced technical data.

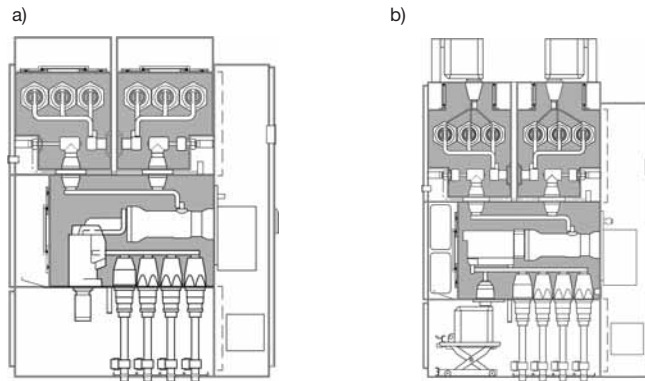


Fig. 8-29

Metal-enclosed gas-insulated switchgear with double busbar, type ZX2

- a) Incoming feeder panel, 2,000 A, with 4 parallel cables and current and voltage sensors
- b) Incoming feeder panel, 2,000 A, for 4 parallel cables, with conventional control equipment: current and voltage transformers with process variables of 1 A and 100 V

In both the ZX2 and ZX1 series, an additional double panel with two outgoing feeders is now available, requiring a width of only 400 mm per feeder for applications up to 24 kV and 630 A at 25 kA. These double panels leave the manufacturer's works as completely tested units and are connected directly to the adjacent panels at site without any additional gas work, using the tried and tested plug-in technology.

Gas-insulated switchgear with switch-disconnectors and circuit-breakers

Gas-insulated switchgear technology is becoming a subject of increasing interest for distribution systems and smaller industrial consumers. Because the high performance data of the installations described in the previous section are not required, special switchgear series have been developed for this application. A major characteristic of this application is the use of switch-disconnectors for feeders with cables and overhead lines and in combination with fuses for protection of small transformers.

Figure 8-26 shows cross-sections of variants from the ZX0 switchgear series in block design. SF_6 is used as the insulating gas and quenching medium for the switch-disconnectors for all rated voltages.

The switch-disconnectors integrated into the panels as three position switches include the function of the earthing switch for the feeder. The contact blades are actuated by the same mechanism with one actuating shaft for each function. The combination device as a switch-disconnector meets the same requirements as a switch-disconnector tested and manufactured as a single unit as per IEC 60265-1 (VDE 0670 Part 301). The requirements of IEC 62271-200 (VDE 0671 Part 102) apply for the earthing function (with short-circuit current-making capacity).

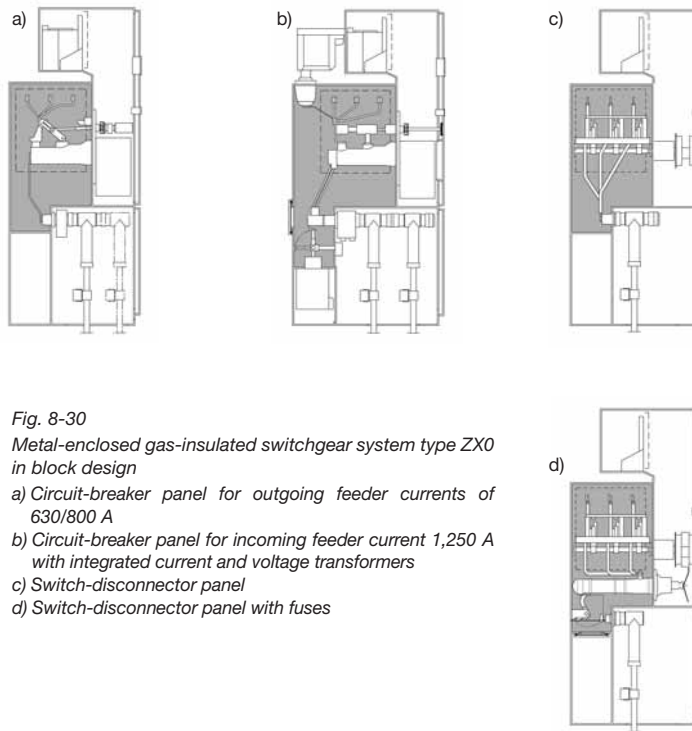


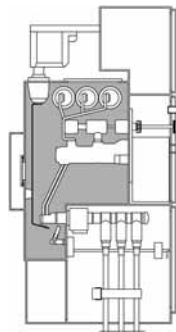
Fig. 8-30
Metal-enclosed gas-insulated switchgear system type ZX0
in block design
 a) Circuit-breaker panel for outgoing feeder currents of 630/800 A
 b) Circuit-breaker panel for incoming feeder current 1,250 A with integrated current and voltage transformers
 c) Switch-disconnector panel
 d) Switch-disconnector panel with fuses

In order to check that the cables are off-circuit before earthing, voltage indicator plugs can be inserted into test sockets at the front of the panels. These sockets are connected to the taps of field grading electrodes inside the cable-plug bushings.

The circuit-breaker panels of this type of switchgear have vacuum interrupters with a cast resin enclosure as arc-quenching systems. This also forms the pivot of the 3-position switch for disconnecting and earthing.

The connected cables are therefore earthed via the circuit-breakers. The REF542 plus digital protection and control unit also controls the actuation, interlocking, display and protection functions in the circuit-breaker panel of the ZX0 switchgear system.

The ZX0 switchgear series as a compact all-rounder is available in the block design variants with up to 6 panels grouped together to form a single gas compartment either with manual mechanisms or electrical actuation, and as a variant with individual panel partitioning and manual operation of all switching devices with the option of remote control (figure 8-31).



*Fig. 8-31
Circuit-breaker panel of type ZX0 for
1,250 A in individual panel partitioning
design with voltage metering at the
feeder*

The technical data of the compact switchgear of type ZX0 are as follows: Rated voltage up to 24 kV, rated current for busbar and feeder with circuit-breaker 1,250 A and for feeder with 3-position switch-disconnector 630 A, and rated short-time current (3 s) 25 kA. The insulating gas is SF₆ with a rated filling pressure of 130 kPa. The panel widths are 400 mm and 600 mm for feeder currents > 800 A and for individual panels; the height is 2100 mm (2250 mm when increased space is required for secondary systems) and the panel depths are 850 mm and 1000 mm for feeder currents > 800 A and for individual panels.

Gas-insulated ring-main units (RMUs) for secondary energy distribution

There are two basic designs in use for the application of ring-main units:

- Systems with a common gas volume inside a common enclosure with a preset number (e.g. 3 or 4) of feeders
- Panels mounted side by side with the opportunity for subsequent extension

Figure 8-32 shows such systems of type SafeRing with common enclosures for all three feeders and the possibility of extension in type SafePlus.

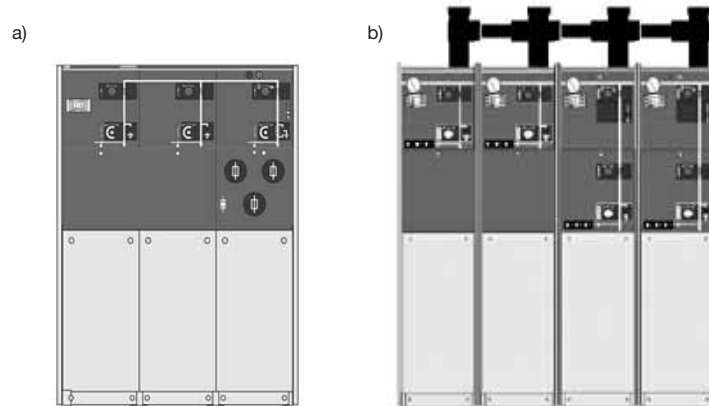


Fig. 8-32

Elevations of ring-main units

a) Ring-main unit of type SafeRing

b) Ring-main unit of type SafePlus

SF₆-switch-disconnectors are also used here to switch the connected cables and overhead lines. For protection of transformers, either a vacuum circuit-breaker with electronic protection (configuration CCV, figure 8-32a) or a switch-disconnector in combination with HRC fuses (configuration CCF, same dimensions as CCV) can be supplied.

Every panel has an earthing switch with specified making capacity to earth the connected cables. In order to check that the cables are off-circuit before earthing, voltage indicator plugs can be inserted into test sockets at the front of the panels. These sockets are connected to capacitive pick-offs on the cable plug bushings.

The switch-disconnectors and circuit-breakers of the switchgear can be remotely actuated with motor-operated mechanisms.

The technical limit data and dimensions of the SafeRing ring-main unit are as follows: Rated voltage up to 24 kV, rated current for the C panel 630 A, for the F panel in accordance with the fuse current, and for the V panel 200 A. Rated short-time current (3 s) up to 21 kA for the C and V panels; F panel with limitation by HRC fuse. The insulating gas is SF₆ with a rated filling pressure of 130 kPa. The dimensions are dependent on the number of panels per unit: widths are 696 mm (2 panels), 1021 mm (3 panels) and 1346 mm (4 panels). The heights in the same order are 622, 947 and 1272 mm, and the depths 663, 983 and 1313 mm.

8.2.6 Control systems for medium voltage switchgear

Conventional secondary technology

A wide range of devices for protection, control and monitoring tasks is available for conventional secondary technology in medium voltage switchgear installations. The planning engineer selects the required units and combines them into one installation. The output variables from the encoders are predominantly standardized to 1 A for current and 100 V for voltage.

The information on measured values, switchgear status and fault messages is transmitted through parallel wiring from the various medium voltage panels to a main control desk or a telecontrol system. Records, data storage, graphical measured value processing, help information when faults occur and self-monitoring functions are not possible with this technology.

Microprocessor control systems

The implementation of digital system designed for the requirements of medium voltage networks allows a number of much more powerful solutions at moderate expense. A system of this type is divided into the bay level, the switchgear level and the control room level (see also section 14.4).

At the bay level autonomously operating, modular and multifunctional devices that can be adapted for the required protection, control and regulating tasks by appropriate software are used. These monitoring devices are installed directly in the low voltage compartments of the medium voltage panels. Here, all measured values, switch positions and messages from the panels are acquired, processed and sent over a serial (unified) interface. The device, which operates independently of the next hierarchical level, combines the protective functions, the switching position display, the measured value display and the local operation of the switchgear, which is protected against maloperation, in one single housing. Its modular design makes it adaptable for the panel-specific protection tasks and selectively or in combination it controls functions such as motor protection, overcurrent definite-time protection, overvoltage and undervoltage protection, earth fault detection, distance protection, differential protection and disturbance recording. It has comprehensive self-monitoring functions and also allows events to be sorted by time with real-time stamping.

The multifunctional protection and control unit REF542 plus is a device of this type. It can optionally be implemented autonomously for one panel only or integrated into a higher-order automation system.

8.3 Terminal connections for medium voltage switchgear

8.3.1 Fully insulated transformer link with cables

Plastic-insulated cables and fully insulated (plug-in) cable terminals provide a number of operational improvements in substation design when consistently used at the interfaces between cables and station components. The key component for a new type of cable link, as shown in figure 8-33, between the power transformer and the switchgear installation is a multiple transformer terminal to figure 8-34 for four parallel power cables. The multiple terminal is designed for a voltage of up to 36 kV and enables currents of up to 3,150 A. The module can be retrofitted to all power transformers. In addition to the operational advantages, this technology offers savings because the transformer no longer requires a cable rack. For more information on plug connectors for power cables, see section 13.2.8.

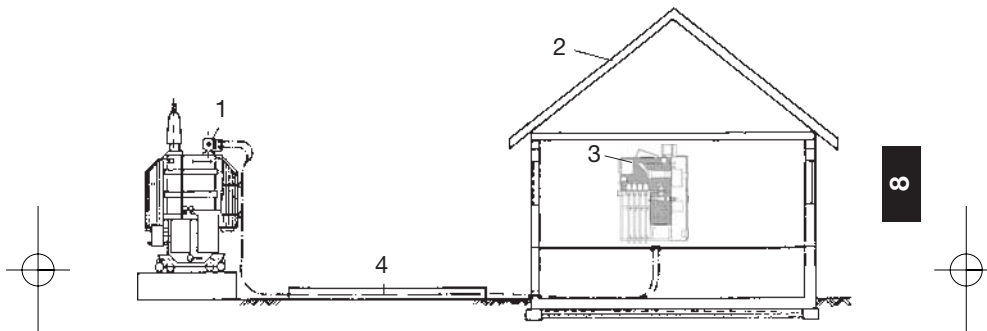


Fig. 8-33

Substation design with fully insulated cable link to the transformer

1 Multiple transformer terminal, 2 Substation building, 3 Switchgear, 4 Cable link in a protective conduit

Fig. 8-34

Multiple transformer terminal

a) Elevation

b) Sectional view

1 Cable plug

2 Cast resin body with sockets

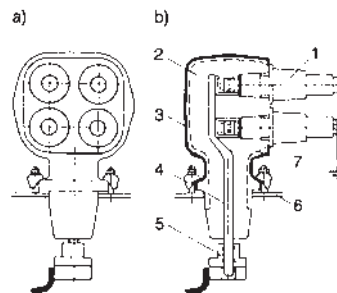
3 Metal casing

4 Conductor bar

5 Contact system

6 Transformer housing

7 Control shield



8.3.2 Solid-insulated bar connection

An option for making bar connections with low space requirements is to use prefabricated epoxy resin-insulated capacitor-controlled single-phase conductors. They are available for service voltages of up to 72.5 kV and for operating currents of up to 5,000 A.

Design of the bar system

The preferred conductor material is an aluminium alloy with high mechanical strength and low weight. A high voltage coating is first applied to the entire surface of the circular or tubular conductor, and the appropriate insulation for the voltage level, consisting of paper and a special cast resin impregnation, is applied to that (figure 8-35), with capacitive control provided by conducting layers at the ends. The covering layer at earth potential is fully embedded in the insulation. For outdoor use the bars are also enclosed in a protective tube of aluminium or a flexible metal hose. The space between the bar itself and the protective cover is then filled with cast resin.

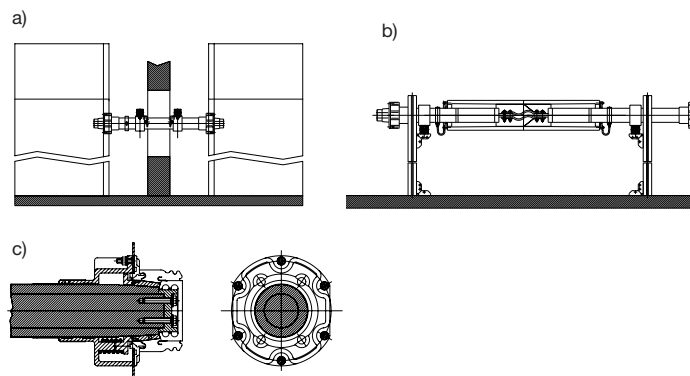


Fig. 8-35

Arrangement of a solid-insulated conductor bar for indoor use

- a) Connecting bar between two switchgear sections with a wall opening
- b) Connecting bar between two switchgear sections with cast resin-insulated, capacitively controlled joint
- c) Inner cone plug for connection to gas-insulated switchgear

The bars are manufactured in sections of up to 12 m in length. Single or multiple bends are available as required made to fit the assembly and connection dimensions. The bars are connected rigidly or flexibly to the devices or panels with screw or plug-type terminals. Individual lengths are joined with special insulating cylinders. The recommended phase clearances, e.g. 200–300 mm at 2,500 A, correspond to the phase spacings of the switchgear. Standard support structures and clamps withstand the short-circuit forces. The earth connections comply with the relevant specifications.